Recent Advances in Acarology, Volume I

EFFECTS OF THE INSECTICIDE DIFLUBENZURON ON SOIL MITES OF A DRY FOREST ZONE IN BRITISH COLUMBIA

Valin G. Marshall

Department of Fisheries and the Environment
Canadian Forestry Service
Pacific Forest Service Centre
Victoria, B. C.

INTRODUCTION

Experimental spraying with the insecticide diflubenzuron during an outbreak of the Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDonnough), at Kamloops, British Columbia, provided an opportunity to study the effects of this insecticide on soil mites. The objective was to study qualitative and quantitative changes in the mite fauna in the top six cm of the soil, where numbers of individuals and species were unsually high. Results for three and 12 months following two application rates are reported here.

Diflubenzuron, a stomach insecticide which is effective against many insects, inhibits chitin synthesis and kills insects by disrupting the moulting process (Post and Vincent, 1973), but little information is available on its effects on the soil biota (Marx, 1977). Lipa and Chmielewski (1976), in a laboratory study, found that only 60-70% of larval *Tyrophagus putrescentiae* (Schrank), whose food contained over 1000 ppm diflubenzuron, reached the adult stage and they attributed this mortality to the mechanical effect of diflubenzuron dust, which covered the mites' bodies and also lowered the humidity of the food. They suggested that lower dosages of diflubenzuron were not inimical to *T. putrescentiae,* because some mites of the family Acaridae lack chitinous hypostracum in the cuticle; therefore, the effect of this insecticide on these mites will be different from that on insects.

Since chitin occurs in bacteria, lichens, blue green algae, fungi and arthropods (Allison, 1957; Tracey, 1968; Muzzarelli, 1977), large-scale use of diflubenzuron may reduce soil mites directly through its effect on cuticle synthesis or indirectly through changes in the food chain, both of which could adversely affect soil fertility.

Copyright © 1979 by Academic Press, Inc.
All rights of reproduction in any form reserved.
Vol. I: ISBN 0-12-592201-9

MATERIALS AND METHODS

The work was done in a Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, Forest Zone, a few km north of Kamloops (50.30° N, 120.24° W), where the mean annual precipitation is generally less than 300 mm and mean monthly temperatures are −6°C for January and 21°C for July. Two sites were selected: one at Palmer Forsyth Road and the other at Tod Mountain Road, 11 km away. Both sites were about 600 m above sea level and supported a 100-year-old forest of mainly Douglas-fir, with small components of ponderosa pine, *Pinus ponderosa* Laws., and lodgepole pine, *Pinus contorta* Douglas.

The Palmer Forsyth Road stand averaged 462 stems per hectare, with dominant trees 19.5 m. tall. The soil was an Orthic Grey Luvisol with an organic layer (L, F, H) averaging 2 cm. The insecticide contained 140 g (a.i.) of diflubenzuron per hectare and was applied as a water-base emulsion at the rate of 11.2 litres per hectare. The emulsion contained 10% ethylene glycol and 3.8 g. of rhodamine B-Extra-S dye, and was applied by a fixed-wing plane with conventional boom and T8010 nozzles, on 18 June 1976.

The Tod Mountain Road stand averaged 495 stems per hectare, with dominant trees 30 m tall. The soil was a degraded Utric Brunisol with combined organic layers averaging 1.9 cm. The diflubenzuron insecticide was applied as in the previous site, but at the rate of 280 g. (a.i.) per hectare, on 15 June 1975.

In a check and a diflubenzuron-sprayed area, 320 m apart, a circular 60-m-diameter plot was selected and divided into three sectors. On each sampling date, six randomly-selected cores were removed from each sector, giving 18 cores per treatment. Cores were taken by a 5-cm-diameter sampler similar to that described by Vannier and Vidal (1965). At the Palmer Forsyth Road site, samples were taken on three occasions: one pre-spray sampling (76/5/19), one month before spraying, and two post-spray samplings, 2 weeks (76/6/29) and 3 months (76/9/22) after diflubenzuron application. At the Tod Mountain Road site, samples were taken only once, one year after diflubenzuron application.

Cores were placed in polyethylene bags and transported 400 km by car to the laboratory. The cores were then divided into two sections: 0-3 cm (mainly L, F, H layers) and 3-6 cm of the upper mineral horizons, and each section was placed intact in an inverted position into a canister-type apparatus (Lussenhop, 1971). Extraction was carried out for 7 days. Specimens were counted in petri dishes under binocular microscopes at 50x magnification. Identification of species was normally made under binocular microscopes, but samples of representative species were permanently mounted for detailed examination with a compound microscoope.

Population counts were transformed to square roots, to compensate for widely varying counts including zeros, and analyzed as a completely randomized design. Significance ($P \leq 0.05$ and 0.01) of each mean difference was determined by the Student-Newman-Keuls' multiple range test (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Fifty-six taxa were recovered from the Palmer Forsyth Road site and 64 from the Tod Mountain Road site, but only 30 of these showed significant changes from diflubenzuron application (Table I). The values for total mites per core, which also includes species not significantly affected, are given to show the relative abundance of significantly affected species. The net decrease or increase in taxa, relative to the check, for the individual soil layers is shown under the appropriate columns; those for the 0-6 cm soil depth are between columns.

In the Palmer Forsyth Road site, the direct effect of diflubenzuron was evident 2 weeks after application from the reduction of 6 species when both soil layers are considered. These values omit *Belba* sp. and *Liochthonius* n. sp. 1, which were significantly higher ($P \leq 0.05$) in the 0-6 cm soil depth of the pre-spray calibration of the check (2:0 and 13:3, respectively), and *Propelops pinicus* and *Trhypochthonius tectorum,* which were significantly affected in the 3-6 cm layer, but not for the total 0-6 cm soil depth. The diminution did not increase substantially 3 months after application when 7 species were reduced. During this 3-month period, only 3 species, *Scutacarus quandrangularis, Stigmalychus* n. sp. and *Schwiebia terrana,* increased in numbers.

The initial reduction of 7 species in the Palmer Forsyth Road site 3 months after spraying was also matched by 7 species in the Tod Mountain Road site 1 year later. These values omit *Coccorhagidia pittardi* and *Eremaeus foveolatus,* which showed a significant change in one layer, but not in the 0-6 cm soil depth. In the Tod Mountain Road site, however, 6 species had increased over the check, almost equalling the 7 species that were reduced. These included the prostigmatids *Cocceupodes breweri, Eupodes* sp., *Stigmalychus* n. sp. and a Bdellidae sp. and the cryptostigmatids *Belba* sp. and *Tectocepheus velatus. Liochthonius* n. sp. 2 increased in the top soil layer, but not in total 0-6 cm soil depth. The reduction of individual species did not affect the total mite population, which showed no significant changes, during the 3-month period after spraying, nor one year later. Increases in certain other species apparently compensated for those that were reduced.

Except for *Nanorchestes* n. sp., Erythraeidae sp., *S. terrana, Liochthonius* n. sp. 3 and *Suctobelbella* sp., all other significantly affected mites inhabited both sides, but only a few species showed consistent trends in population changes following the spray application. Increases in *S. quadrangularis* and *Tarsonemus* n. sp. were temporary, while that in *S. terrana* appeared to be sustained. Unfortunately, *S. terrana* was not found in the Tod Mountain Road site to allow further interpretation of this early response. *Stigmalychus* n. sp. increased greatly on most sampling dates, while *Tectocepheus velatus* was reduced initially, but showed higher numbers in the sprayed plot at Tod Mountain Road one year after diflubenzuron application. *Eremaeus foveolatus* showed reductions from spraying in both sites for 2 sampling periods,

TABLE I.
Population Density of Mite Taxa Showing Significant Changes to Diflubenzuron Spraying in Two Douglas-Fir Sites in British Columbia

Taxa	Mean Number of Mites Per Core (Check Plot : Sprayed Plot)[a]					
	Palmer Forsyth Road				Tod Mountain Road	
	76.6.29[b]		76.9.22[c]		76.5.19[d]	
	0-3 cm	3-6 cm	0-3 cm	3-6 cm	0-3 cm	3-6 cm
MESOSTIGMATA						
Amblyseius nicola Chant	0:0	0:0	0:1	0:0	1:0**	0:0
Zerson spp.	2:2	1:0	5:1**	1:1	4:3	0:0
PROSTIGMATA						
Alicorhagia usitata Th., Me & Ry.	26:27	18:19	47:33	40:12**	5:9	2:4
Cocceupodes breweri Strandtmann	1:1	0:0	4:4	2:1	1:4	0:1*
Coccorhagidia pittardi Strandtmann	0:0	0:0	0:1	0:0	0:0	1:0*†
Eupodes sp.	6:6	7:3	18:13	9:7	3:6*	1:1
Nanorchestes n. sp.	—	—	—	—	1:0*	0:0
Scutacarus quadrangularis (Poali)	3:10*	1:9*	14:11	5:7	30:9	10:1
Stigmalychus n. sp.	73:49	39:165**	52:55	83:175	1:14*	1:33*
Tarsonemus n. sp.	4:5	2:3	11:21	2:5	5:1**	0:0
Bdellidae	7:8	3:1	11:11	4:4	1:5**	0:1*
Cunaxidae	2:0**	0:0	1:0	0:0	1:2	0:0
Erythraeidae	3:0**	1:0*	0:0	0:0	—	—
ASTIGMATA						
Schwiebia terrana Jacot	4:10**	1:2	7:12*	1:3	—	—
CRYPTOSTIGMATA						
Belba sp.	3:0**	1:0**	9:0**	2:0*	0:1*	0:0
Brachychthonius bimaculatus Willmann	13:16	9:4*	20:10	9:1*	4:4	3:8
Eremaeus foveolatus Hammer	13:8	1:0**	24:21	4:3	12:2*†	0:0
Joshuella sp.	1:0	0:0	2:0**	0:0	0:0	0:0
Liochthonius n. sp. 1	4:9	6:3	8:6	10:4*	0:0	0:0
Liochthonius n. sp. 2	0:0	0:0	0:0	0:0	4:5	0:4*†
Liochthonius n. sp. 3	—	—	—	—	2:0*	1:0*
Oppiella nova (Oudemans)	2:1*	3:0**	7:2**	6:1*	2:1	0:0
Opiella simplissimus (Jacot)	0:0	1:0	0:0	1:0	1:0**	4:0*
Parachipteria nivalis (Hammer)	2:0*	1:0**	2:1	0:0	0:0	0:0
Propelops pinicus Jacot	1:1	1:0*†	1:0	0:0	2:4	0:0
Quadroppia ferrumequina Jacot	0:0	0:0	0:0	1:0	3:1*	0:0
Scheloribates sp.	0:0	1:0*	0:0	0:0	0:0	0:0
Suctobelbella sp.	—	—	—	—	1:0*	0:0
Tectocepheus velatus (Michael)	5:7	1:0	25:9**	2:1	6:17*	0:0
Trhypochthonius tectorum (Berlese)	6:7	3:1*†	14:12	5:2	5:2	0:0
No. of species (decrease/increase)	4/2	9/2	4/0	4/0	7/5	3/4
No. of species for 0-6 cm soil depth (decrease/increase)	6/3		7/1		7/6	
Total mites per core	277:262	138:259	393:314	252:291	130:128	30:57

[a] Mean of 18 cores, each 19-6 cm² sampled to a depth of 6 cm.
[b, c, d] Two weeks, 3 months and 1 year after spraying, respectively
*, ** Significance at $P < 0.05$ and 0.01
† Significant change in one layer not reflected in the combined 0-6 cm soil depth

although a reduction in the Tod Mountain Road site one year after spraying was evident only in the 0-3 cm soil layer.

Response within acarine orders was varied. The Mesostigmata were generally adversely affected, the significantly changed taxa showing a reduction in numbers. Among the Prostigmata, an equal number of species increased as decreased. All Cryptostigmata showed a reduction in numbers immediately following diflubenzuron application, but 2 species had increased compared to the check one year after application in the Tod Mountain Road site. The only abundant representative of the Astigmata, *S. terrana,* increased after spraying, supporting Lipa and Chmielewski's (1976) thesis that low dosages of diflubenzuron would not be inimical to some Acaridae.

In the 0-3 cm soil layer, 4 species were reduced in the Palmer Forsyth Road site, whereas 7 species were reduced in the Tod Mountain Road site. Although the 3-month post spray data for the 0-6 cm soil depth for the Palmer Forsyth Road site and the Tod Mountain Road site showed a reduction of 8 and 10 species, respectively, the greater species diminution in the 0-3 cm layer of the latter site possibly resulted from the higher application rate. Data on the precise vertical distribution on each species would be difficult to obtain, because large numbers of samples would be required to overcome the patchy horizontal distribution of many mite species, seasonal movement in the soil profile, variation in soil organic matter, and random penetration of the spray in the soil. However, the total reduction of most of these species for the 0-6 cm layer does not indicate a downward movement from the 0-3 to the 3-6 cm layer, but rather a sustained effect of diflubenzuron on mites in the top soil layer at Tod Mountain.

Affected species were not restricted to a particular trophic level. Significant increases occurred among predators such as *C. breweri* and Bdellidae sp., and saprophages such as *Stigmalychus* n. sp. and *Liochthonius* n. sp. 2. Similarly, decreases occurred among predators such as Cunaxidae sp. and Erythraeidae sp., and saprophages such as *Alicorhagia usitata, E. foveolatus* and *Oppiella nova.* Only 4 species recovered in the check plot were not found in the sprayed areas and these might have been eliminated by the spray. Again, these included predators (*Amblyseius nicola* and *Nanorchestes* n. sp.) and saprophages (*Joshuella* sp. and *Suctobelbella* sp.).

The study demonstrates the importance of working at the species level in determining the effects of agricultural and forestry practices on soil mites. Although the total mite population was unchanged up to one year after spraying, some species were reduced, while others seem to have disappeared from the sprayed plots. Changes effected in the check because of defoliation, for example, more litter fall and possibly higher ground temperatures, might have caused quantitative faunal changes, but these would be unlikely to increase the species composition of the site.

It is concluded that a single application of diflubenzuron up to a rate of 280 g (a.i.) per hectare had no drastic effect on any of the trophic levels of the

mites. However, there is still need for vigilance, because a few species seem to have been eliminated from the sprayed area, while others had not returned to the "normal" level one year after diflubenzuron application. It is not clear how much changes in the soil mite population will affect soil fertility.

SUMMARY

Effects of 2 rates of diflubenzuron, 140 and 280 g (a. i.)/ha, applied by aircraft, were examined on soil mites in a Douglas-fir *(Pseudotsuga menziesii)* forest. Total mite population was not significantly affected two weeks, three months and one year after application, but a few species found in the check were not found in the sprayed plot. Other species, which were significantly reduced initially, had not recovered to the "normal" level of the check. Generally, members of the Mesostigmata and Cryptostigmata were adversely affected. Among the Prostigmata, the same number of species increased as decreased; whereas an increase was noted in the Astigmata. At least two trophic levels were altered, with increases and decreases occurring among predators and saprophages.

ACKNOWLEDGEMENTS

I thank Miss Andrea Hall and Mr. L. A. Bjerstedt for technical assistance and Dr. C. Simmons for the statistical analysis.

REFERENCES

Allison, F. E. (1957). pp. 85-94, *In* "Soil, the Year Book of Agriculture 1957." USDA, Washington.

Lipa, J. J. and Chmielewski, W. (1976). *Bull. Acad. Pol. Sci., Sie. Sci. Biol.* **24**, 381-384.

Lussenhop, J. (1971). *Pedobiologia* **11**, 40-45.

Marx, J. L. (1977). *Science* **197**, 1170-1172.

Muzzarelli, R. A. A. (1977). "Chitin." Pergamon Press, Oxford.

Post, L. C. and Vincent, W. R. (1973). *Naturwissenschaften* **60**, 431-432.

Steel, R. G. D. and Torrie, J. H. (1960). "Principles and Procedures of Statistics with Special Reference to the Biological Sciences." McGraw-Hill Book Co. Inc., New York.

Tracey, M. V. (1968). *In* "Advances in Comparative Physiology and Biochemistry." (O. Lowenstein, ed.). Academic Press, New York.

Vannier, G., and Vidal, P. (1965). *Rev. Ecol. Biol. Sol.* **2**, 333-337.